U. S. DEPARTMENT OF THE INTERIOR

Geological Survey

THE MAUZY FORMATION, A NEW STRATIGRAPHIC UNIT OF PERMIAN AGE IN WESTERN KENTUCKY

By

Thomas M. Kehn, John G. Beard, and Allen D. Williamson

Open-File Report 81-790

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards. Any use of trade names is for descriptive purposes only and does not imply endorsement by the USGS.

1981

CONTENTS

	Page
Abstract	1
Introduction	1
Previous nomenclature	3
Mauzy Formation	3
Contacts	7
Lower boundary of Mauzy Formation	7
Lower boundary of Permian System	7
Location of drill holes Gil-30 and CS-1801	8
Composite type section of the Mauzy Formation	8
Composite section of the Sturgis Formation	10
Upper section	11
Lower section	12
Reference section of the upper part of the Carbondale Formation	13
References cited	15

ILLUSTRATIONS

Page

Figure 1. - Correlation chart showing the nomenclature of this report and of earlier reports for Pennsylvanian and Permian units in the western Kentucky coal field 2

Figure 2. - Index map of the western Kentucky coal field and the type area of the Mauzy Formation showing the location of two stratigraphic test holes..... 4

Figure 3. - Geologic map showing area underlain by the Mauzy Formation..... 5

THE MAUZY FORMATION, A NEW STRATIGRAPHIC UNIT OF PERMIAN AGE IN WESTERN KENTUCKY

By

Thomas M. Kehn, John G. Beard [1], and Allen D. Williamson [1]

ABSTRACT

We recommend that the Mauzy Formation be named and defined as a rock-stratigraphic unit in the western Kentucky coal field. Paleontological studies of the uppermost strata of the Sturgis Formation indicate that they are, at least in part, of Early Permian age and thus, should be reassigned to the Mauzy Formation. These strata are preserved in a fault block in the Sturgis, Union County, Kentucky, area; whether strata of similar age exist elsewhere in the Eastern Interior (Illinois basin) coal field area is unknown, but Lower Permian strata probably did cover part or all of this area prior to being eroded. The type section of the Mauzy Formation consists of interbedded shale, siltstone, and limestone and minor amounts of sandstone and coal. It has a known thickness of about 390 feet but may be as much as 1,300 feet thick, as suggested by projected structural data. The Mauzy Formation conformably overlies the Sturgis Formation; the contact between the formations is at the base of a predominantly limestone sequence, in which Permian age fusulinids have been identified, and is above a sequence of shale, siltstone, sandstone and coal that contains spores and pollen of Pennsylvanian age.

INTRODUCTION

Detailed geologic investigations supported by core drilling in the Bordley 7 1/2-minute quadrangle (Kehn, 1975a) and the Sturgis 7 1/2-minute quadrangle (Kehn, 1975b), Kentucky have revealed a small down-faulted structural block of the Rough Creek fault system; the block contains a stratigraphic section more than 3,600 feet thick that was assigned to the Pennsylvanian System (Kehn, 1973). Glenn (1912a, b, and 1922) and Lee (1916) reported the Pennsylvanian section to be much thinner (fig. 1) and, because of the paucity of stratigraphic and structural control, did not recognize these younger strata in their reports of this area. Dunbar and Henbest (1942) summarized information on fusulinid-bearing horizons in the Illinois part of the Eastern Interior coal field and reported that fusulinids from the uppermost marine limestone beds were of Late Pennsylvanian age. They also stated that equivalent strata might be present in western Kentucky.

A core drilling program in the western Kentucky coal field, funded by the Kentucky Geological Survey, was recently concluded. The core Gil-30, drilled in 1976, was taken from the fault block in which the thickest Pennsylvanian section had been identified. Samples of limestone from this core were obtained for paleontological studies, and this report is based, in part, on the result of that investigation and, in part, on a revision of structural control from data obtained in the core drilling program and reinterpretation of the previous mapping.

1. Kentucky Geological Survey, Henderson, KY 42420

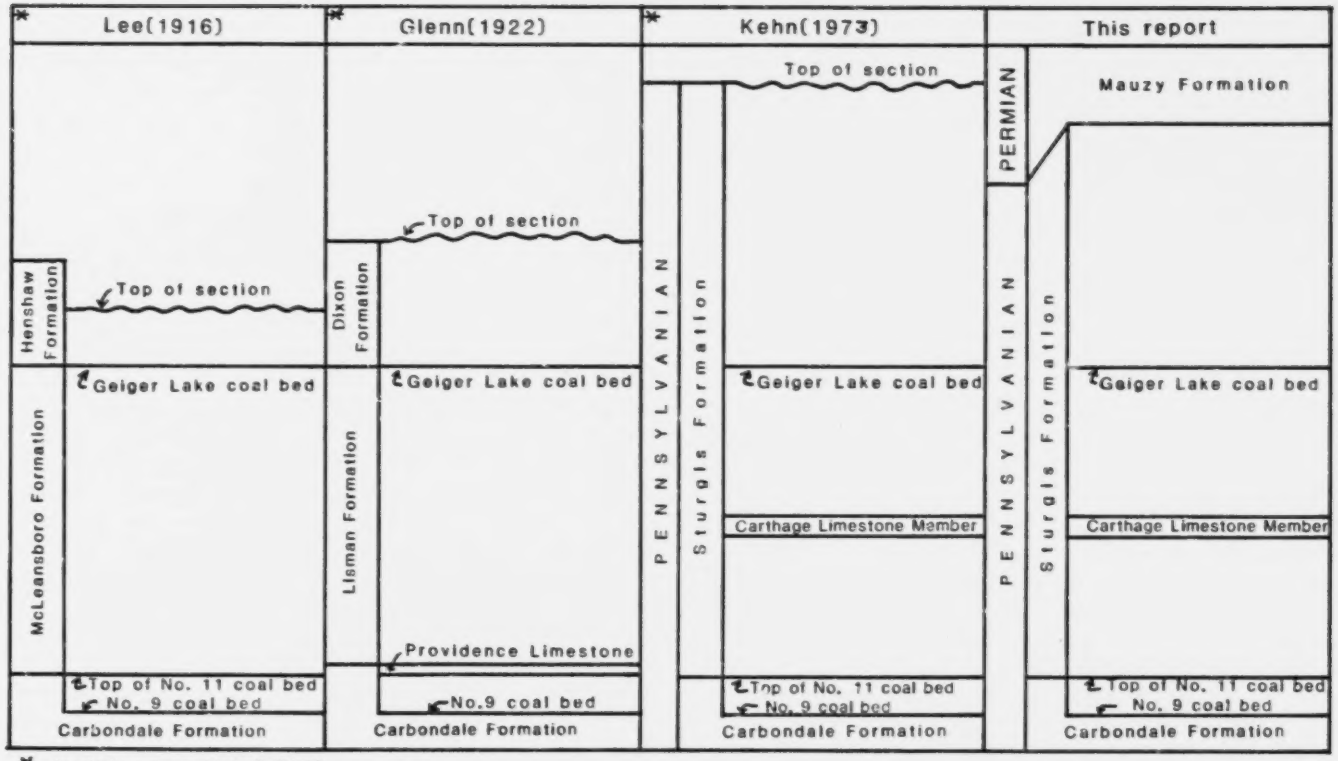

Figure 1.--Correlation chart showing the nomenclature of this report and of earlier reports for Pennsylvanian and Permian units in the western Kentucky coal field.

We recommend that the rocks formerly assigned to the uppermost part of the Sturgis Formation be reassigned to the Mauzy Formation, a new stratigraphic unit, that is all or in part of Early Permian age. A summary of the nomenclature is given in figure 1.

PREVIOUS NOMENCLATURE

Kehn (1973) modified the nomenclature of the uppermost part of the rock stratigraphic section of Pennsylvanian age in western Kentucky and named and defined the Sturgis Formation (fig. 1). Later, mapping in the Bordley and Sturgis quadrangles (Kehn, 1975a, b; this report, figs. 2, 3) revealed the presence of about 470 feet of younger strata not previously described. These rocks, although containing a much greater percentage of limestone and calcareous siltstone than previously described deposits of the Sturgis, were included as part of the Sturgis Formation. We propose that the base of the limestone and calcareous siltstone sequence be considered the base of the Mauzy Formation and the top of the Sturgis Formation. The Sturgis Formation, as thus redefined, is stratigraphically restricted to about 2,039 feet in thickness.

The Sulphur Springs coal bed, about 200 feet below the top of the Sturgis Formation, is equivalent to or slightly younger than the Pittsburgh coal bed of the Appalachian area (R. A. Peppers, written communication, 1978). It is the youngest stratum of Late Pennsylvanian age for which paleontological data are available in the western Kentucky coal field.

MAUZY FORMATION

The area underlain by the Mauzy Formation is largely covered by loess and alluvium. Hence, surface criteria for differentiating the Mauzy Formation from the Sturgis Formation for stratigraphic and paleontological purposes could not be found. The core from hole Gil-30 (figs.2, 3) confirmed the existence of the thick limestone and calcareous siltstone beds previously reported by Kehn (1975a, b) and also provided material for paleontological studies of the contained fusulinids. Hence, the composite type section for the formation is designated as the 340 feet of measured section from corehole Gil-30 drilled by the Kentucky Geological Survey and at least 50 feet of younger strata inferred to exist in a nearby ridge about 1 mile west of Cap Mauzy Lake (fig. 3), from which the name Mauzy is taken. The corehole was about 7 1/2 miles northeast of Sturgis, Kentucky, in the northwest part of the Bordley quadrangle (see figs. 2, 3 and p. 8 for additional location data). The core is on file at the core library of the Kentucky Geological Survey, Lexington, Kentucky.

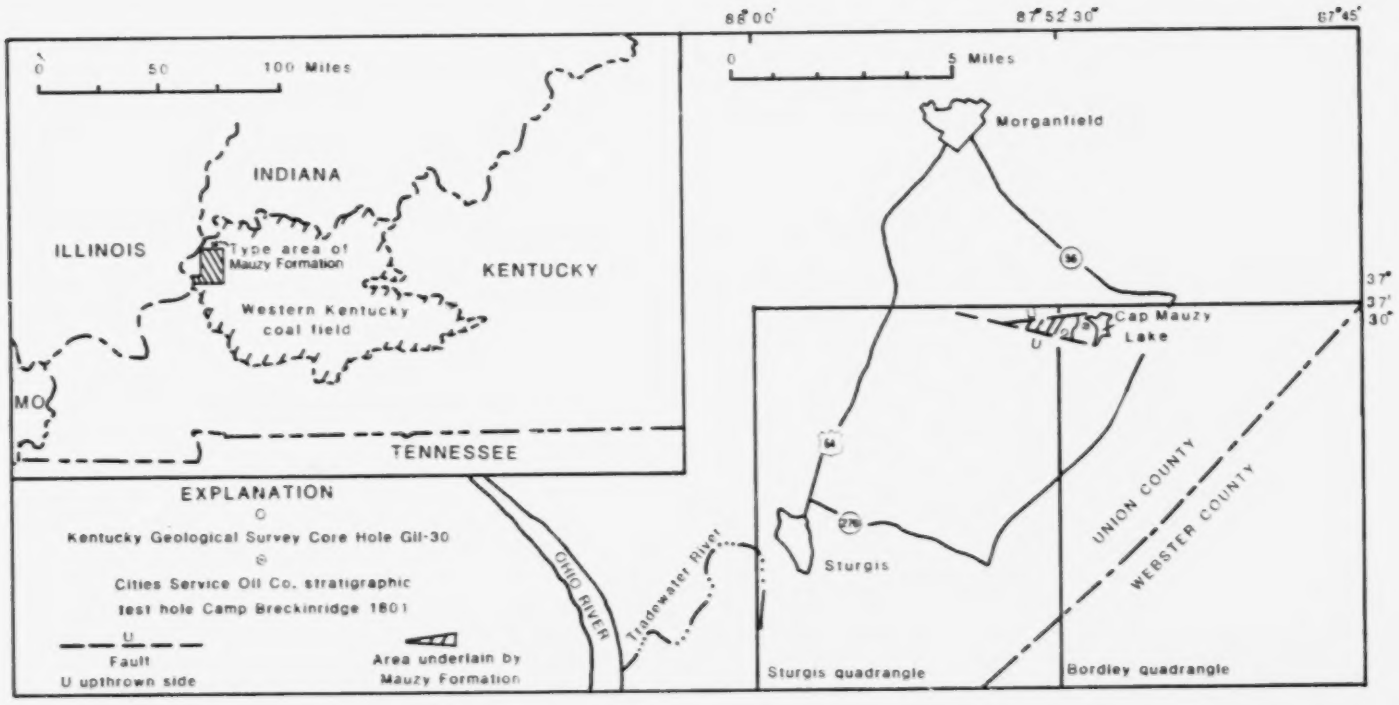

Figure 2.--Index map of the western Kentucky coal field and the type area of the Mauzy Formation showing the location of two stratigraphic test holes.

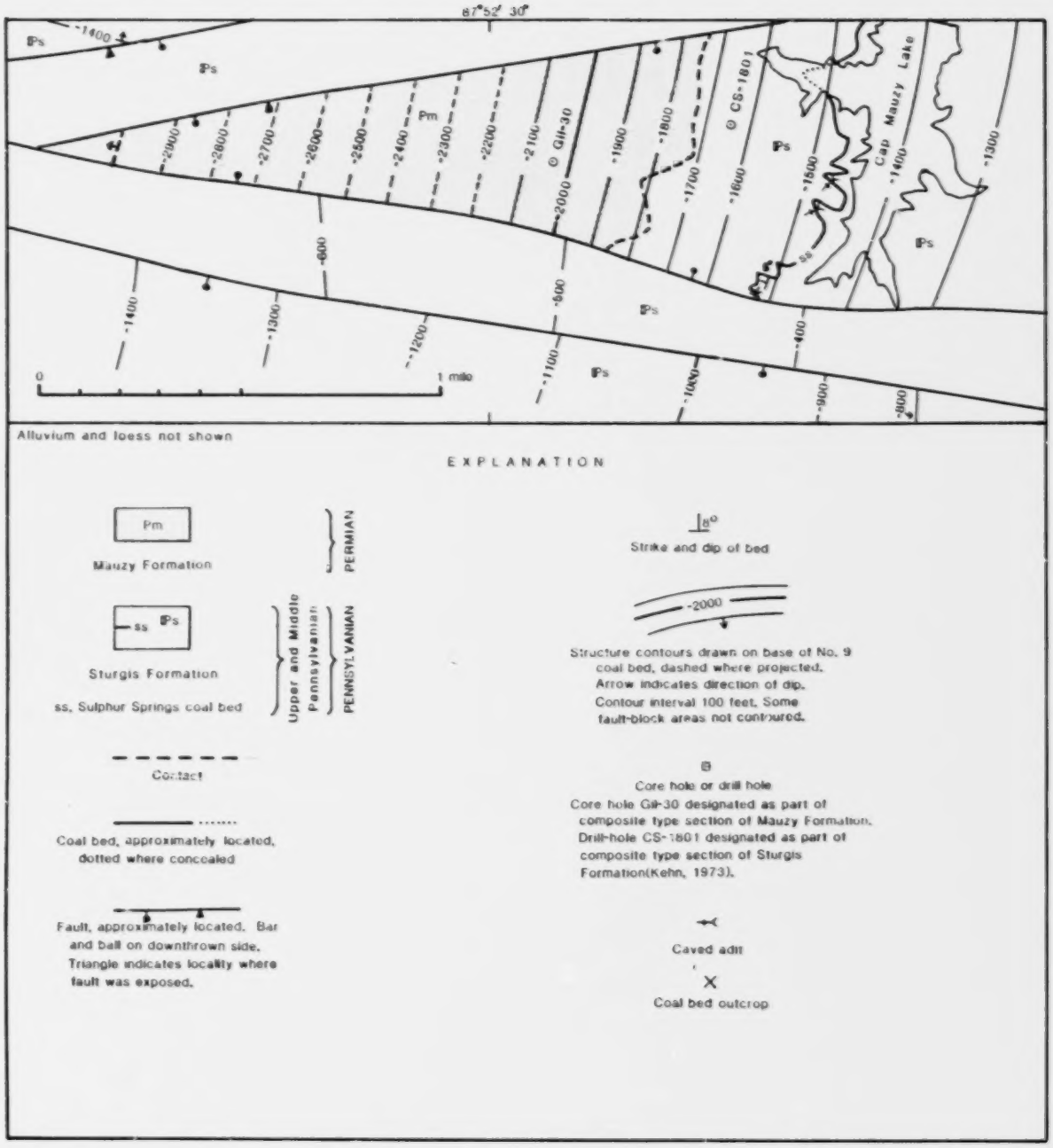

Figure 3.--Geologic map showing area underlain by the Mauzy Formation.

Modified from Kehn (1975a,b).

A generalized description of the type section of the Mauzy is included in this report. A thin bed of limestone at a depth of 193.9 to 195.8 feet (243.9 - 245.8 ft. p. 9) contains a few large Triticites sp. of Early Permian age (Douglass, 1979). About 145 feet of strata below the fusulinid-bearing limestone is also assigned to the Mauzy Formation because the strata are lithologically similar to rocks above the limestone.

The Mauzy Formation is composed of interbedded shale, siltstone, and limestone and minor amounts of sandstone and coal. Shale ard siltstone, the dominant rock tvpes in the cored section, make up about 70 percent of the formation. The shale and siltstone, generally interlaminated, are commonly light gray to black or green to greenish gray. The Mauzy is poorly to well laminated in even to wavy beds, except for steep crossbeds at a depth of 69.0 to 80.7 feet in the cored section (see p. 8). It also contains a few thin sandstone beds. The shale and siltstone generally are calcareous and micaceous along bedding surfaces. A coal bed and two thin carbonaceous shale beds are present in the lower part of the cored section.

Limestone makes up about 25 percent of the Mauzy Formation. In the Sturgis Formation, limestone makes up less than 5 percent of the formation (Kehn, 1973, p. B8). The limestone of the Mauzy Formation is generally light gray to tan to buff. It is mostly very fine to fine grained and clayey to silty where it grades into or is interbedded with shale or siltstone. These calcareous sequences have been described as a permicrite by G. R. Dever, Jr., and W. C. Macquown, Jr. (personal communication, 1978), which is not common to the western Kentucky coal field. The limestone is mostly even bedded and is as much as 10 feet thick. Marine fossils have not been recognized except in the thin limestone near the middle of the cored section.

Sandstone makes up less than 5 percent of the formation. It is medium gray and fine grained. The sandstones are generally thin bedded; cross bedding, cut-and-fill structures and interlaminations of shale and siltstone are common.

Coal is a minor constituent of the Mauzy Formation, as only three very thin coaly or carbonaceous shale beds were found in the lower part of the cored section. Additional coal beds could be in the loess-covered 50 feet of the type section above corehole Gil-30.

The total thickness of the formation is not known because of structural uncertainties and probable erosion of the top part of the section within the fault block. The formation may be as much as 1,300 feet thick as indicated by projected structure contours drawn on the No. 9 coal bed (fig.3), which is widely used in western Kentucky as a structural datum. The contours are based on dips known from the meager outcrop and drill-hole data. A total thickness of 1,300 feet or more for the Permian in western Kentucky would not be improbable as shown by McKee and others (1967, pl. 7). However, the structure probably is more complex than that shown in figure 3. The strata may have dips more or less than those projected or dip direction could be reversed and the 390 feet described

here might be the maximum thickness preserved in the fault block and be essentially the maximum thickness deposited in the Eastern Interior region.

CONTACTS

Lower Boundary of Mauzy Formation

The Mauzy Formation appears to overlie the Sturgis Formation conformably and may intergrade with it. Deposition is assumed to have been continuous from one formation to the other because no evidence of a disconformity is seen in the core. We recommend that this contact be arbitrarily placed at the base of the limestone sequence in the uppermost 340 feet (390.0 feet of the described section, p. 10) of strata cored at the drill-hole Gil-30 locality; the core contains a much greater percentage of limestone and calcareous shale above the contact and a much greater percentage of sandstone and coal below it.

The upper limit of the Mauzy Formation is not defined because it has been removed by erosion or is present only in the western part of the fault block (fig. 3) where stratigraphic and structural control is not available to determine its placement. Younger rocks, if they ever existed, have been removed by erosion or are covered by Quaternary alluvium or Pleistocene loess in the western part of the fault block.

Lower Boundary of Permian System

The boundary between the Pennsylvanian and Permian Systems cannot be precisely defined because paleobotanical and paleontological data are insufficient. For convenience, the systemic boundary is tentatively placed at the proposed contact between the Mauzy and Sturgis Formations in corehole Gil-30. This boundary is based in part on gross lithologic character and on age differences of beds above and below the boundary.

The Sulphur Springs coal bed, about 200 feet below the boundary, is reported (R. A. Peppers, written communication, 1978) to be equivalent to or younger than the Pittsburgh coal bed and is presently the youngest coal bed of Late Pennsylvanian age identified in the western Kentucky section. The unnamed limestone, about 140 feet above the boundary, contains a few fusulinids of Early Permian age. Because deposition appears to have been continuous, all or part of the 340 feet of stratigraphic section between the Sulphur Springs coal bed and the fusulinid-bearing limestone bed mentioned above could be assigned to a transition zone, or the boundary could be placed elsewhere within this interval of the section. Similarly, rocks at the Pennsylvanian-Permian boundary in the Appalachian area are gradational, and the contact is arbitrarily chosen (McKee and others, 1967, p. 36) or it is not precisely defined (Henry and others, 1979, p. 85).

LOCATION OF DRILL HOLES Gil-30 and CS-1801

[See figures 2 and 3]

Hole Gil-30; 300 ft. from S. line and 1,650 ft. from E. line of Carter coordinate section 13, N-20, or 2,800 ft. from north boundary and 700 ft. from west boundary of Bordley 7 1/2-minute quadrangle, Union and Webster Counties, Kentucky. Surface altitude 455 ft. above mean sea level. Core log datum 455 ft. above mean sea level. Drilled 1976.

Cities Service Oil Company, stratigraphic test hole, CS-1801, 700 ft. from S. line and 600 ft. from W. line of Carter coordinate section 12, N-20, or 2,150 ft. from north boundary and 3,150 ft. from west boundary of Bordley 7 1/2-minute quadrangle, Union and Webster Counties, Kentucky. Surface altitude 520 ft. above mean sea level. Driller's log and geophysical electric log datum 526 ft. above mean sea level. Drilled 1965.

COMPOSITE TYPE SECTION OF THE MAUZY FORMATION

[The composite type section of the Mauzy Formation consists of the 340 feet of measured section from corehole Gil-30 drilled by the Kentucky Geological Survey and at least 50 feet of younger strata inferred to exist in a nearby ridge about 1 mile west of Cap Mauzy Lake, approximately 1,000 feet of additional strata may be present as shown by the structure (fig. 3). However, no lithologic data are available and structural control is uncertain; therefore no description can be given for this part of the section. The following descriptive log is generalized from the core description by personnel of the Kentucky Geological Survey. The detailed descriptive log and core can be studied at that Survey, in Lexington, Kentucky]

	Depth (feet)
Permian System	
Mauzy Formation	
Surface, includes loess, soil, and bedrock probably similar to rock types described below	0-69.0
Shale, medium-gray to greenish-gray, slightly silty; siltstone laminations dip 10°-20°	69.0-80.7
Sandstone, medium-gray, fine-grained; thin dark shale laminations at top, thicker toward base; base sharp	80.7-106.1
Shale, gray to dark-gray, calcareous	106.1-107.9
Limestone, gray to buff, finely crystalline to dense, slightly clayey; calcite-filled fractures	107.9-113.3
Shale, medium-gray, calcareous	113.3-113.8

Limestone, gray to buff----------113.8-114.8

Shale, medium-gray to greenish-gray; clayey at top; thin beds of limestone at base----------114.8-120.6

Shale, medium-gray, clayey; calcareous toward base--------120.6-124.1
Limestone, buff to gray, finely crystalline to dense; clayey toward base----------124.1-126.7

Shale, medium-gray, clayey----------126.7-128.9
Limestone, light-gray to tan, dense; calcite-filled fractures near top; green to gray shale parting 0.25 ft. thick in middle of unit----------128.9-132.7

Shale, light-gray to greenish-gray----------132.7-133.5

Limestone, buff to gray, clayey; becoming more shaly toward base----------133.5-139.0

Shale, dark-gray, calcareous----------139.0-140.0

Limestone, light-gray to tan to buff; dense; scattered fractures; argillaceous in part----------140.0-147.9

Shale, dark-gray, calcareous; few thin lenses of medium gray limestone in basal part----------147.9-150.0

Limestone, medium-gray, argillaceous, dense----------150.0-159.9

Shale, gray to greenish-gray, calcareous; scattered limestone nodules----------159.9-170.8

Limestone, medium-gray, argillaceous, dense----------170.8-172.2

Shale, dark-gray, calcareous----------172.2-176.1

Limestone, light-gray to tan to buff, argillaceous, dense; dark-gray to greenish-gray shale partings----------176.1-202.8

Shale, greenish-gray to dark-gray, thinly laminated in part, silty; few thin laminations of very fine grained sandstone in middle of unit----------202.8-243.9

Limestone, light- to medium-gray, very argillaceous; fossiliferous, contains a few fusulinids of a large Triticites sp. of Early Permian age----------243.9-245.8

Shale, dark-gray, thinly laminated; few siltstone laminations near base----------245.8-252.8

Sandstone, light-gray, very fine grained, calcareous; scattered clay and shale nodules and laminations--------252.8-253.5

	Depth (feet)
Shale, very dark gray, clayey, carbonaceous	253.5-266.5
Limestone, tan to buff, finely crystalline to dense; fractured, nodular appearance; interbedded with greenishgray to gray shale	266.5-290.9
Shale, gray to greenish-gray, poorly bedded	290.9-295.0
Shale, black, carbonaceous	295.0-295.1
Shale, gray to greenish-gray; scattered silt laminations; limestone nodules at top and base	295.1-325.0
Shale, dark-gray; scattered silt laminations	325.0-373.1
Coal, bony, shaly near top	373.1-374.1
Shale, dark-gray to green, calcareous	374.1-375.0
Limestone, brown to tan, finely crystalline to dense	375.0-376.8
Shale, dark-gray	376.8-377.2
Limestone, brown to tan; argillaceous toward base	377.2-379.1
Shale, dark-gray	379.1-380.0
Limestone, light-gray to brown, dense, argillaceous	380.0-388.2
Shale, dark-gray, calcareous	388.2-389.5
Limestone, light-gray to brown, dense, argillaceous. We recommend that the contact between the Mauzy and Sturgis Formations be arbitrarily placed at base of this unit. We recommend that the boundary between the Permian and Pennsylvanian Systems also be tentatively placed at this contact	389.5-390.0

COMPOSITE SECTION OF THE STURGIS FORMATION

[The upper and lower sections of the Sturgis Formation are described below. The descriptions are modified from those given by Kehn (1973, p. B11-B23). Depths have been modified to give depth below the datum of the Gil-30 hole and thus to provide continuity with the composite type section of the Mauzy Formation given above]

Upper section

[This section includes 200 feet of strata described from the core taken at the corehole Gil-30 locality and at the drill hole CS-1801 locality. It corresponds to the 70 - 270-foot part of the upper section of the Sturgis Formation (Kehn, 1973, p. B11-B12). The systemic boundary between the Permian and Pennsylvanian Systems may be within this unit]

Pennsylvanian System
Upper Pennsylvanian Series
Sturgis Formation (part):

	Depth (feet)
Shale, green to gray, calcareous; clayey and brown to reddish near middle and silty at base	390.0-395.9
Sandstone, medium-gray, very fine grained, argillaceous	395.9-402.4
Shale, dark gray	402.4-410.0
Shale, very dark gray to black, argillaceous; scattered limestone bands and nodules; carbonaceous in upper part	410.0-440.5
Coal, bright and dull banded; fine pyrite and calcite-filled veins at top	440.5-442.3
Shale, medium-gray, clayey, nonbedded	442.3-443.3
Coal, dull to bright, fusain partings; bony and contains carbonaceous shale partings at top and base; calcite laminations in bony coal at base	443.3-454.3
Shale, medium-gray, clayey, nonbedded; plant impressions at top; limestone nodules in lower part	454.3-468.8
Shale, medium-gray, and limestone, tan, dense; silty toward base	468.8-480.1
Shale, dark-gray; laminations of light-gray siltstone and light-gray, fine-grained sandstone at base	480.1-490.0
Sandstone, light- to medium-gray, fine-grained	490.0-493.3
Shale, greenish-gray to black: carbonaceous at base, pyrite nodules and laminations	493.3-500.8
Coal, dull to bright, much fusain; pyrite bands and pyrite on cleat; much bony coal and carbonaceous shale bands	500.8-505.8
Shale, medium-gray, nonbedded; calcareous, contains white limestone nodules	505.8-520.4

	Depth (feet)
Limestone, light-gray to gray, finely crystalline to dense	520.4-526.0
Shale, medium-gray; scattered silty and calcareous laminations and nodules	526.0-538.0
Shale, black, carbonaceous; few pyrite nodules	538.0-541.1
Sandstone, medium-gray, fine- to medium-grained; scattered thin carbonaceous shale laminations, argillaceous; sandy at top	541.1-556.5
Shale, dark-gray; scattered silty laminations	556.5-565.1
Shale, black, carbonaceous, fissile	565.1-567.1
Limestone, brown to gray, finely crystalline to dense; in beds 1-2 feet thick separated by dark-gray to black carbonaceous shale beds 0.2 ft. to 0.9 ft. thick	567.1-572.8
Shale, dark-gray to black; calcareous; limestone laminations at top; carbonaceous; bony coal at base	572.8-589.0

Lower Section

[The lower section of the Sturgis Formation is about 1,839 feet thick.]

Pennsylvanian System
Upper Pennsylvanian Series
Sturgis formation (part):

	Depth (feet)
Coal, dull to brightly banded. The Sulphur Springs coal bed (unnamed coal bed of Kehn, 1973, p. B12, 268-270 ft.) contains a spore assemblage that is equivalent to or younger than that from the Pittsburgh coal bed (R. A. Peppers written communication, 1978)	589-591
Siltstone, sandstone, shale, limestone, coal, and underclay: siltstone, light- to dark-gray; interbedded with sandstone and shale. Sandstone, light-gray, very fine to fine-grained. Shale, light-gray to black, carbonaceous. Limestone, brown and gray, dense, silty, and shaly. Coal, impure, generally in thin beds. Underclay, light- to dark-gray	591-1,416
Coal (Geiger Lake coal bed), bright	1,416-1,417

	Depth (feet)
Siltstone, shale, sandstone, limestone and coal: Siltstone, light- to dark-gray. Shale, light-gray to black, clayey to sandy. Sandstone, light-gray, interbedded with shale and siltstone. Limestone, medium-gray. Coal, thin, generally impure.	
Lisman coal bed, 6 in. thick at base	1,417-1,776
Siltstone, shale, sandstone, limestone, and coal: Rock types are similar to those described above. No. 18 coal bed, thin, in middle of unit	1,776-1,957
Limestone (Carthage Limestone Member), light-olive-gray, dense, fossiliferous	1,957-1,964

Pennsylvanian System
Middle Pennsylvanian Series
Sturgis Formation (part):

Shale, siltstone, sandstone, limestone, coal, and underclay: Rock types are similar to those rock types described for units above. The unit includes three named coal beds and the Madisonville Limestone Member, a single bed 5 feet thick at base	1,964-2,248
Siltstone, sandstone, shale, limestone, coal, and underclay: Rock types are similar to those described for units above. Unit includes four named coal beds and the Providence Limestone Member at base. Basal part of claystone of the Providence Limestone Member in contact with top of the No. 11 coal bed of the Carbondale Formation	2,248-2,429

REFERENCE SECTION OF THE UPPER PART OF THE CARBONDALE FORMATION

[Below is a modified log description of about 124 feet of the Carbondale Formation penetrated by stratigraphic test hole CS-1801, Cities Service Oil Company. Depths to described units have been modified to provide continuity with the composite sections of the Mauzy and Sturgis Formations given above]

Pennsylvanian System Middle Pennsylvanian Series Carbondale Formation (part):	Depth (feet)
Coal, hard, bright; No. 11 coal bed. No. 11 coal bed at depth of 2,047-2,051 feet	2,429-2,433
Claystone, light-gray; interbedded with light-gray siltstone in lower part	2,433-2,436

	Depth (feet)
Sandstone, light-gray, fine-grained	2,436-2,440
Siltstone, light- to dark-gray, shaley	2,440-2,464
Shale, light-gray to black at base	2,464-2,473
Coal, No. 10 coal bed	2,473-2,474
Shale and siltstone, dark-gray	2,474-2,487
Sandstone, medium-gray, fine-grained	2,487-2,522
Shale, dark-gray, silty; carbonaceous in lower part	2,522-2,548
Coal, bright, hard; No. 9 coal bed	2,548-2,553

REFERENCES CITED

Douglass, R. C., [1979], The distribution of fusulinids and their correlation between the Illinois Basin and the Appalachian Basin, in Palmer, J. E., and Dutcher, R. R., eds., Depositional and structural history of the Pennsylvanian System of the Illinois basin. Part 2, Invited papers: Ninth International Congress of Carboniferous Stratigraphy and Geology, Urbana, Ill., 1979, Field Trip 9, pt. 2: Illinois State Geological Survey Guidebook Series 15a, p. 15-20.

Dunbar, C. O., and Henbest, L. G., 1942, Pennsylvanian Fusulinidae of Illinois: Illinois State Geological Survey Bulletin 67, 218 p.

Glenn, L. C., 1912a, The geology of Webster County: Kentucky Geological Survey Report of Progress 1910-1911, p. 25-35.

_____ 1912b, A geological reconnaissance of the Tradewater River Region, with special reference to the coal beds: Kentucky Geological Survey Bulletin 17, 75 p.

_____ 1922, The geology and coals of Webster County: Kentucky Geological Survey, ser. 6, v. 5, 249 p.

Henry, T. W., Lyons, P. C., and Windolph, J. F., Jr., 1979, Upper Pennsylvanian and Lower Permian(?) Series in the area of the proposed Pennsylvanian System stratatype, in Englund, K. E., Arndt, H. H., and Henry, T. W., eds., Proposed Pennsylvanian System stratatype Virginia and West Virginia: The American Geological Institute, AGI Selected Guidebook Series No. 1, p. 81-85.

Lee, Wallace, 1916, Geology of the Kentucky part of the Shawneetown quadrangle: Kentucky Geological Survey, ser. 4, v. 4, pt. 2, 73p.

Kehn, T. M., 1973, Sturgis Formation (Upper Pennsylvanian), a new map unit in the western Kentucky coal field: U.S. Geological Survey Bulletin 1394-B, 24 p.

_____1975a, Geologic map of the Bordley quadrangle, Union and Webster Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-1275, scale 1:24,000.

_____1975b, Geologic map of the Sturgis quadrangle, western Kentucky: U.S.Geological Survey Geologic Quadrangle Map GQ-1273, scale 1:24,000.

McKee, E. D., Oriel, S. S., and others, 1967, Paleotectonic maps of the Permian System: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-450, 164 p., 20 pls.